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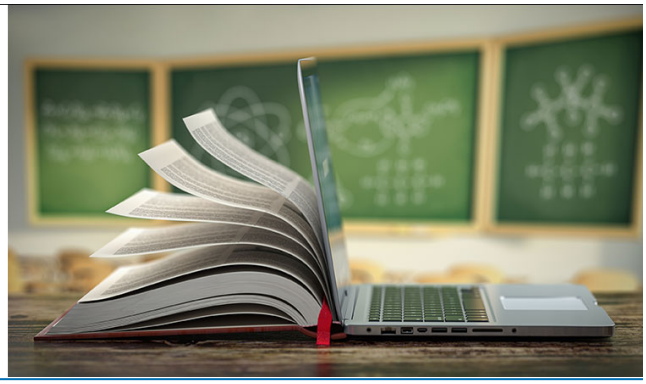

Gold Cementation in Percolation Mode Using Dendritic Zinc Powders

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Abstract. Present article is devoted to study of electrolytic zinc powders usage features in gold mining industry. Electrolytic zinc powders characterized by dendritic shape and a high specific surface area. These features of electrolytic zinc powders provide a number of advantages for gold cementation from alkaline cyanide solutions. Dendritic form of electrolytic zinc powder makes it possible to reduce zinc layer hydraulic resistance on filtering surface, which is important when using cementation technologies based on filtration of gold-bearing solution through zinc powder layer. High specific surface area of electrolytic zinc powders favourably affects the rates of gold recovery from cyanide solutions, which is shown in cementation experiments from model and real (industrial) solutions.

1. Introduction

Cyanide leaching is most widespread gold raw materials processing method. One of most important stage of cyanide leaching technology is gold precipitation from productive solutions. Cementation method is often used because it has advantages, in particular high speed of process and ability to obtain a product containing metallic gold in one stage. Improvement of cementation processes should be aimed on developing conditions for use of cheaper cementing metals and dispersed systems based on them, reducing unit costs, and obtaining more concentrated cement sediments.

Technological execution of cementation process, as a rule, is based on percolation model of interaction of cementing metal and gold-bearing solution. Most widespread method is the Merrill-Crowe process [1, 2], based on filtration of productive solution through a mixture of zinc powder coated with lead dendrites and inert porous additive.

At analyzing features of cementation technology with finely dispersed zinc powder, a number of negative aspects should be noted. Cementation at Merrill-Crow plants is carried out in a cyclic mode. Forced solution supply to press filter with addition of zinc powder and inert additive is carried out until filter surface pores are closed. Most often, stop occurs when hydraulic resistance of sediments on filtering surface increases excessively. High hydraulic resistance of system limits layer thickness and cycle times. At the same time, periodically, due to operational errors at dosing inert porous additive and mixing it with zinc powder, situations arise when filtering surface are closed already on first day of cementation process. After precipitate removing and filter cloth regeneration, press filter is brought back into operation and solution supply is resumed. Specified feature of work leads to increased labor costs for maintenance and energy consumption.

Important features of Merril-Crow technology are need for a large filtration area and high overall dimensions. The large filtration area is due to small thickness of zinc layer, which in practice does not exceed 5-10 mm.

At using fine powders these problems cannot be eliminated. Coarse powders obtained by distillation or melt dispersion have a significantly lower specific surface area, rate of cementation and the completeness of gold deposition when using them are unacceptably low.

Use of coarse powders with high specific surface area can solve the problem of cementing layer high hydraulic resistance. Such zinc powders can be obtained by electro-extraction from alkaline solutions. Alkaline leaching followed by zinc electroextraction has recently been studied in relation to processing of technogenic raw materials (dust from steel-making units, waelz oxides) [3-7]. Due to this, reduction in cost of zinc powder can be achieved.

Earlier, efficiency of gold deposition by dendritic zinc powders from leaching solutions of gravitational concentrates was shown [8, 9]. Purpose of this article is to study physicochemical features of dendritic powders, relatively currently used finely dispersed powders, as well as to study effect of these features on gold cementation parameters.

2. Physicochemical properties of studied zinc powders

In present work following powders were investigated:

1. Zinc powder, used in industrial conditions for gold cementation at gold recovery factories, obtained by distillation of pure zinc (hereinafter referred to as "traditional" powder).
2. Zinc powder obtained by technology of electroextraction from alkaline solutions (hereinafter referred to as "electrolytic" or "dendritic").

Electrolytic powders physical properties can vary significantly depending on electroextraction conditions and initial solution composition [10-21]. To establish effect of electrolytic powders physical properties on gold deposition rates, three samples were obtained at different electroextraction modes (Table 1). Magnesium (cathode) and steel (anode) plates were used as electrodes. Choice of cathode material is due to high hydrogen evolution overpotential and absence of compact layer of initially reducing zinc [22].

Table 1. Conditions under which electrolytic powders were obtained.

	Zinc concentration in solution, mol/dm^3	NaOH concentration in solution, mol/dm^3	Current density, kA/m^2
Electrolytic zinc powder No. 1	0.15	10	2
Electrolytic zinc powder No. 2	0.15	10	0.5
Electrolytic zinc powder No. 3	0.15	2.1	0.5

Morphological composition of electrolytic zinc powders was determined by scanning electron microscopy (Jeol JSM-6390LA). Electrolytic powders have a characteristic dendritic shape (Figure 1). Granulometric characteristics of powders were evaluated using Sympatec HELOS & RODOS laser particle analyzer.

Surface characteristics of electrolytic zinc powders were evaluated by BET method on Gemini VII 2390 automatic surface area and porosity analyzer. Bulk density was determined on a Scott volumetric meter. Content of metallic zinc was estimated by dissolving a weighed portion of powder in hydrochloric acid and analyzing resulting solution. Properties of obtained electrolytic powders are presented in Table 2.

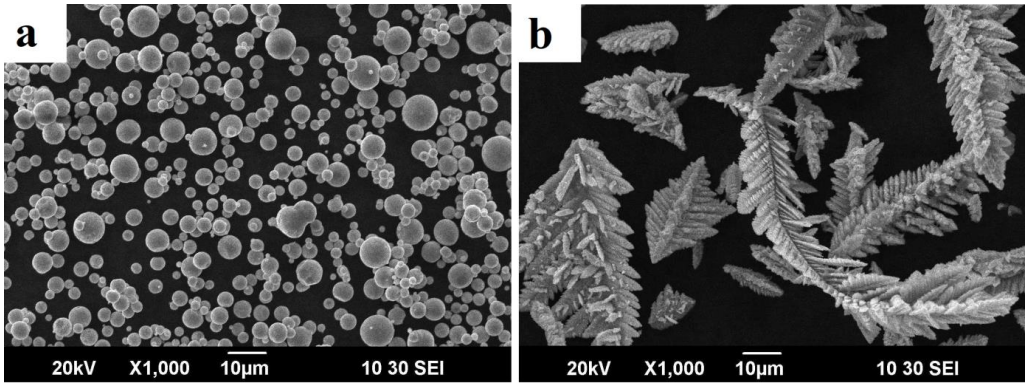

Figure 1. Micrographs of zinc powders with magnification of x1000, traditional zinc powder (A), electrolytic powder No. 1 (B).

Table 2. Physicochemical properties of studied electrolytic powders.

	Bulk density, g/cm^3	Average powder particle size, µm	Powder specific surface area, m^2/g	Content of metallic zinc in powder, %
Traditional zinc powder	2.51	5	1.16	98.5
Electrolytic zinc powder No. 1	0.81	39	3.02	91.0
Electrolytic zinc powder No. 2	0.77	71	2.10	91.3
Electrolytic zinc powder No. 3	0.66	108	1.46	91.5

Most significant distinguishing feature of electrolysis powders is their high specific surface area, 1.3-2.6 times higher than that of traditional powders, despite superior average particle size.

To assess unproductive activity of zinc powders dynamics of zinc sample dissolution (0.1 g) at temperature of 25 °C and vigorous stirring in model alkaline solution (0.1 dm^3) at oxygen absence was studied (Figure 2). Oxygen was removed from solution by addition of Na_2SO_3.

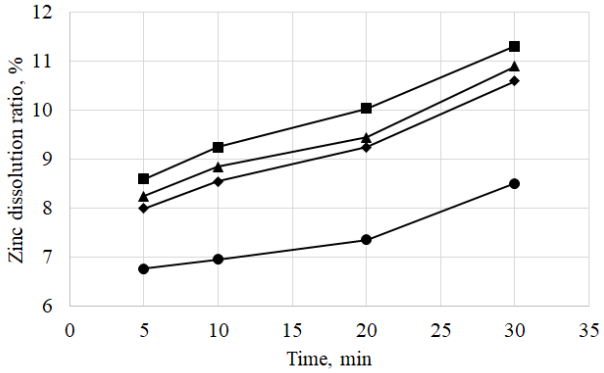

Figure 2. Zinc powders dissolution dynamics (0.04 mol/dm^3 NaCN, 11 pH); ● - traditional powder, ■ - electrolytic powder 39 µm, ▲ - electrolytic powder 71 µm, ♦ - electrolytic powder 108 µm.

Dissolution rate of electrolysis powders exceeds dissolution rate of traditional powder under described conditions. This is primarily due to high content of oxidized zinc. Dissolution of metallic

(not oxidized) zinc under these conditions is difficult, since system oxidation potential is reduced by removal of dissolved oxygen and absence of non-ferrous metal ions.

3. Cementation research methodology

In laboratory studies we used model and real (productive) solutions. Model solutions were prepared by dissolving a pure gold sample in alkaline cyanide solution. Real solution is product of gold-bearing concentrates leaching.

Gold, zinc and associated non-ferrous metals content analysis in initial and spent liquors was carried out on Analytic Jena novAA 300 atomic absorption spectrophotometer. pH value was monitored with an Aquilon pH-410 device.

In accordance with cementation practice, dissolved oxygen was removed from solutions (by adding Na_2SO_3) to prevent increased zinc consumption. Studied zinc powders were coated by dendritic lead before loading into laboratory setup. Lead was precipitated on zinc surface by cementarion; lead was introduced into an alkaline solution in form of lead acetate ($Pb(CH_3COO)_2$) at consumption of 10% of zinc mass.

Inert porous additive was added to traditional powder at lead-coating stage in order to ensure permeability of layer to gold-bearing solution. In experiments with powders obtained by electroextraction from alkaline solutions, inert porous additivewas not added.

Laboratory studies were carried out on cylindrical device with false bottom which simulates cementation technologies based on solution percolation through zinc layer.

Solution was fed to laboratory unit continuously by peristaltic pump, as a result of which it seeped through zinc layer and out of unit bottom. At specified time intervals spent solution was taken and analysed for metal content.

4. Cementation results

It was found that electrolysis powder has a significantly lower hydraulic resistance.

Measurements of powders throughput were carried out on laboratory unit with false bottom porosity of 16-40 μm and diameter of 20 mm at constant productive solution pressure (0.01 MPa), figure 3. Powder sample weight is 1 g. Solution with high non-ferrous metals content is used. When passing alkaline solution containing gold, silver and copper ions powder condition changes due to dissolution and cementation reactions, which increases cementing layer hydrodynamic resistance. For comparison with traditional zinc powder, we used finest available electrolysis powder (39 microns in size), since it is characterized by greatest probability of closing filter surface.

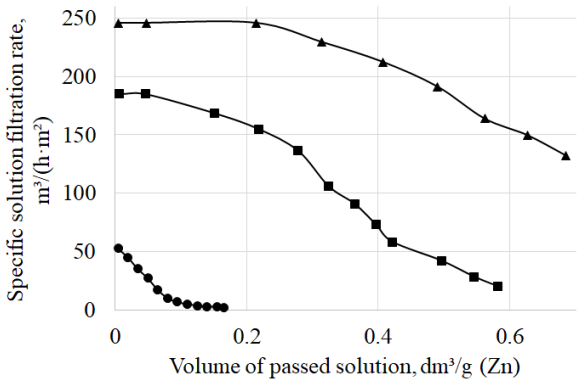

Figure 3. Powder throughput (initial solution: 284.3 μmol/dm^3 Au, ~ 10 mmol/dm^3 Σnon.ferr.met., 0.05 mol/dm^3 NaCN, 11.1 pH); ● - traditional powder without inert porous additive, ■ - traditional powder with inert porous additive, ▲ - electrolytic powder 39 microns without inert porous additive.

Under production conditions on gold processing plants specific productivity of press filter (solution filtration rate) varies near value of 1.5 $m^3/(hour \cdot m^2)$, while solution pressure in system can be pumped up to 1 MPa, and total content of non-ferrous metal ions is 5-10 $mmol/dm^3$. In practice, one work cycle time of Merrill-Crow units lasts up to week; at the end of cycle solution filtration rate decreases, productivity of installations drops. Extension of work cycle time is not an urgent task, since timely removal of commercial precipitate is necessary for economic reasons. However, due to use of dendritic powder, it is possible to achieve an increase in productivity of units by increasing powder layer thickness without increasing load on pumping equipment. Electrolysis powder hydraulic permeability at initial stage exceeds hydraulic permeability of traditional powder with inert porous additive by 1.3 times, which also makes it possible to use equipment of lower power (as a consequence and lower cost) to create required pressure in system.

One of key technological parameters of flow-through cementation process is solution specific feed rate. Study of influence of solution specific feed rate on gold recovery degree is shown in Figure 4. Layer height was fixed for all powders (5 mm). To determine gold recovery degree, a sample of spent solution was taken 10 minutes after the start of experiment (after repeated renewal of solution in volume of installation).

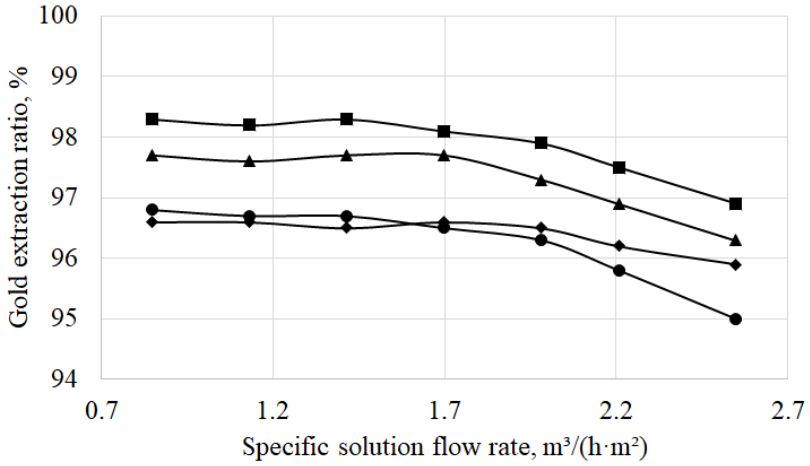

Figure 4. Solution specific flow rate effect on gold extraction ratio (initial solution: 10 mg/dm^3 Au, 2 g/dm^3 NaCN, 11 pH); ● – traditional powder, ■ - electrolytic powder 39 μm, ▲ - electrolytic powder 71 μm, ♦ - electrolytic powder 108 μm.

From data shown in Figure 4, it follows that all zinc powders at rates of solution feeding more than 1.7-2 $m^3/(hour \cdot m^2)$ and low contact duration of solution with zinc begin to precipitate gold with lower efficiency. It is shown that difference in residual gold concentration correlates with specific surface area of studied powders. Highest value of gold recovery degree when using electrolytic powder with particle size of 39 μm and specific surface area of 3.02 m^2/g gave reason to consider this powder as most suitable among other studied electrolytic powders for gold cementation.

As gold and non-ferrous metals precipitate, zinc powders are consumed, for this reason, equilibrium gold recovery (maximum achievable under given conditions, under which cementation is carried out in practice) begins to decrease over time and concentration of gold in spent solution increases.

Nature of change in gold concentration in spent solution during long cementation cycle with electrolytic (39 μm) and traditional powders is shown in Figure 5.

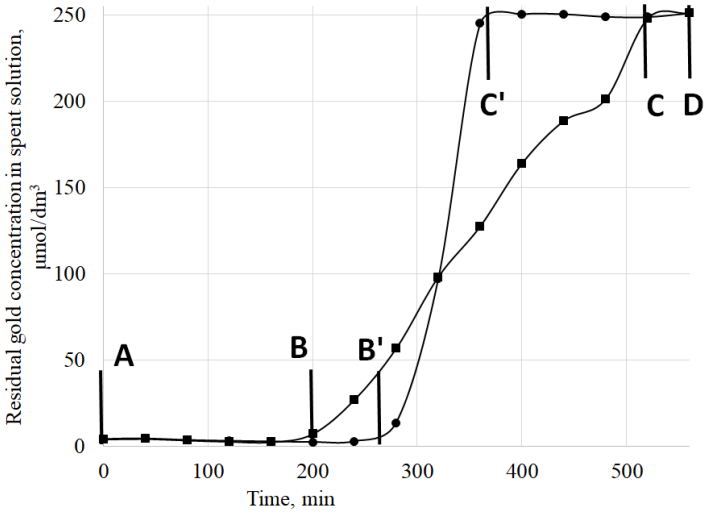

Figure 5. Change in gold residual concentration in solution as zinc is consumed (initial solution: 253.8 μmol/dm^3 Au, 0.04 mol/dm^3 NaCN, 11 pH); ● - traditional powder, ■ - electrolytic powder 39.

Solution specific flow rate for both powders was maintained at level of 1m3/(hour·m2) throughout entire duration of experiment. As follows from data presented, traditional and electrolytic zinc powders at first stage exhibit comparable properties; in both cases, gold precipitation degree in operating mode (sections AB and AB') exceeds 97%. As cementation proceeds, differences in precipitation dynamics are revealed (sections BC and B'C'): when using traditional powder, 260 minutes after experiment start, sharp increase in gold content in spent solution occurs after which cementation stops, during deposition with electrolytic powder gold concentration increasing spent solution is smoother, but decrease of recovery degree begins earlier (200 minutes). Sharp increase of gold concentration in spent solution is probably due to fact that when using traditional powder with spherical shape and uniform particle size distribution (92% of particles fit into range of 2-10 μm), state is achieved in which diffusion through reaction products is completely stops cementation simultaneously with respect to all zinc particles. In this case, unreacted zinc grains remain blocked by reaction products and inaccessible for gold ions in solution. At the same time, electrolytic powder dendrites are overgrown by reaction products unevenly, as a result, cementation reaction rate decreases over a longer period of time. Early increase of gold concentration in spent solution at electroltic powder usage is apparently associated with more intense zinc dissolution in alkaline medium and zinc oxide dissolution (which is higher in electrolytic powder). After passing a certain volume of solution through weighed powders portions, cementation completely stops (sections CD and C'D). Table 3 shows result of analysis of precipitates obtained during long cementation cycle.

Table 3. Result of cementation products analysis.

	Amount of gold passed through zinc sample, μmol	Amount of precipitated gold over entire experiment duration, μmol	Amount of consumed zinc over entire experiment duration, mol(Zn)/mol(Au)
Traditional zinc powder	2369	1364	29.5
Electrolytic zinc powder No. 1 (39 μm)	2369	1522	31.9

Amount of precipitated gold and consumed zinc was determined by dissolving cementate residue with subsequent solutions analysis.

Results indicate that with the same mass of traditional and electrolytic powders, despite shorter duration of section with maximum gold recovery, electrolytic powder, in total, precipitates more gold than traditional powder ones due to smoother increase of gold concentration in spent solution.

5. Conclusion

Electrolytic zinc powders have dendritic structure, which ensures their low bulk density and high specific surface area.

Physical properties characteristic of dendritic powders makes it possible to carry out cementation deposition of gold in percolation mode without use of inert porous additives. Throughput of layer from electrolytic zinc powder is 1.3 times higher than that with use of traditional zinc powder mixed with inert additive.

Gold recovery degree from solution by dendritic zinc powder in area of effective cementation is comparable to that for traditional zinc powder. With a long cementation cycle, due to smoother increase of gold concentration in spent solution, electrolysis powder makes it possible to increase amount of precipitated gold by 5-10%.

Area of gold effective cementation using electrolytic powder is smaller than using traditional zinc powder, however, due to high hydraulic resistance it is difficult to realize this advantage of traditional zinc powder.

6. References

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